K.6

EUMETSAT POLAR SYSTEM

GROUND SEGMENT

EPS GROUND SEGMENT

SYSTEM CONCEPT

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Document Distribution

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1 INTRODUCTION .

1.1 Scope & Purpose

This document provides an introduction to the EUMETSAT Polar System (EPS) ground segment in terms of the key user requirements, a functional system overview and concepts for operations. It also presents the main options currently being assessed for implementation of the various functional elements of the ground segment and highlights key system issues.

This document provides a consolidation of a number of studies which have been undertaken on the EPS ground segment and establishes a baseline system concept for a range of planned Phase A studies and external interface discussions. It is based on work completed by and on behalf of EUMETSAT to date, and it is not intended to constrain the system requirements or design process which will be initiated during the forthcoming Phase A study. Furthermore, this document will allow users to see the way in which the ground segment is being configured and how the data processing scheme is being developed. Such information is necessary to enable users to assess and to express alternative requirements.

The aim has been to provide a high level overview of the system, and the reader is directed to the reference documents in Section 2 for more detailed information and discussion.

1.2 Overview

The principal objective for the EPS ground segment is to distribute quality controlled global data from imagery and sounding instruments operating in a morning polar orbit to the operational meteorological centres of the EUMETSAT member states, to the National Oceanic and Atmospheric Administration (NOAA) and to World Meteorological Organisation (WMO) weather forecasting centres. These data are requited to meet the operational needs of Numerical Weather Prediction (NWP) models as well as synoptic analysis and climate studies. Consequently, the provision of these data needs to be both timely and continuous.

Key features of the operational system include a full range of payload data handling facilities for global users, support to local users and facilities for mission management and satellite operations. A high data rate communications network is required both for data transfers within the ground segment and for dissemination to users. Demands for substantial throughput and processing capacities within the system, high availability requirements and a large number of external interfaces all combine to form a severe operational environment.

However, there is a dual aspect to the EPS ground segment concept which is illustrated in Figure l-l.

As well as the operational facilities which have been described, a range of supporting activities

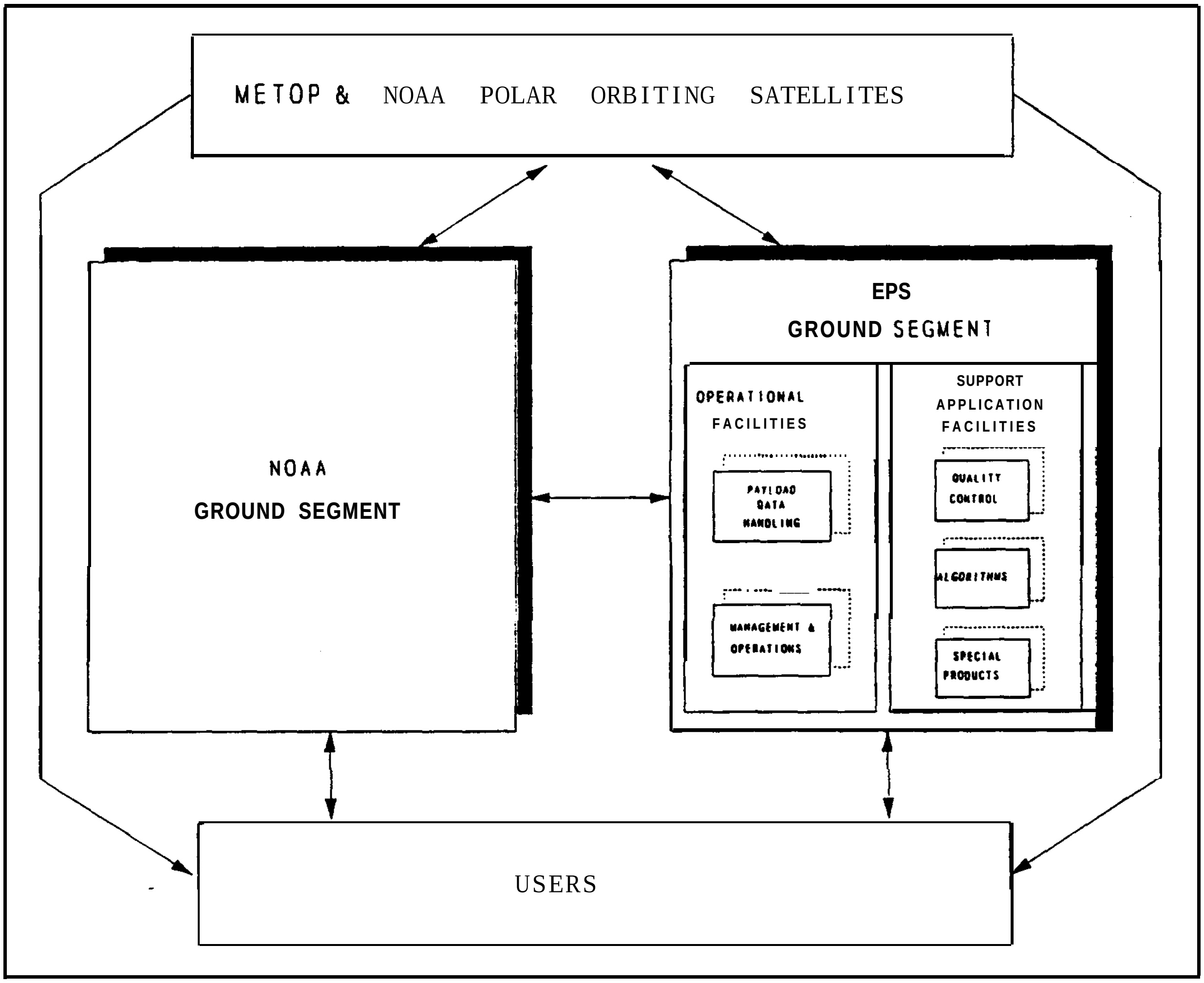

Figure 1-1 Basic concept for the EPS Ground system

are envisaged to be undertaken by Support Application Facilities (SAFs). Whilst not part of the operational system, these will provide a range of essential functions such as:

independent, long term trend analysis and quality control of data sets produced by EPS

development of new processing algorithms and recommendations for future changes to the system production and dissemination of specialist level 2 and 3 products.

Particular SAFs have not yet been defmed. They would be based on the existing infrastructure and meteorological expertise of mereological centres within EUMETSAT Member States, such as those undertaking global or regional numerical weather prediction, and those using satellite data for other forecasting tasks. They will vary in their level of integration with the operational system. Generation of a suite of operational meteorological products would represent the most tightly integrated facility, off-line quality assessment or development of algorithms being only very loosely coupled and a climatological products facility being virtually independent.

1.3 constraints

There are a number of features or requirements which place constraints on the development and operation of the EPS ground system.

Although this is a European programme, it forms part of a coordinated system of polar satellites with NOAA and so there are not only opportunities, but essential user requirements for coordinated development and operations of the EPS and NOAA ground systems.

At a world-world scale, the polar observing system and the global observing system of geostationary satellites together provide a Global Observing System (GOS) for the WMO World Weather Watch (WWW) Programme. Consequently, in Europe, complementarity between the EPS and the future METEOSAT Second Generation (MSG) data processing systems need to be explored.

The new EPS system will need to integrate into an existing community of operational meteorological users within Europe including meteorological centres running global NWP models, centres running regional weather prediction models for Europe and also users connected to the Global Telecommunications System (GTS). This community has established data formats for dissemination of data (for example GRIB and BUFR, see RD4) and also an overall operational schedule controlling the timing and specification of data and products received.

Future international initiatives such as the Global Climate Observing System (GCOS) and the Committee for Earth Observing Systems (CEOS) may also impact the EPS ground system, both in the contribution to be made by EPS and also in terms of the complimentary role of data from other sources which impact the ground segment specification. GCOS will focus primarily on climate issues. However, the current baseline for the EPS ground system is to assume that (a) the EPS ground system only acts as a communications gateway for climate data and (b) that the design of the archive will be optimised for commonality with other archive systems and for ease of access to long data runs.

It is also clear that any sharing of responsibilities for either the implementation or operation of the individual ground segment elements should not affect the overall service for global users. The value of data for weather forecasting is based both on its quality and timeliness.

1.4 Definitions

Throughout the description of the ground segment, the processing level definitions which have been assumed are provided in Table 1-1.

Table 1-1 Processing Level Definitions

LEVEL	DEFINITION OF LEVEL
0	Raw data. Basic bit stream from the observing system.
1A	Instrument data in full resolution, reconstructed and redundancy removed. Radiometric and geometric calibration computed and appended but not applied to level 0 data.
1B	Calibrated, Earth-located and quality controlled data, expressed as radiances or brightness temperatures. House-keeping data sets should be appended to ensure that the data are reversible.
2	Earth located pixel values converted to geophysical parameters on an orbital basis.
3	Geophysical parameters analyzed/mapped to a standard grid. This normally involves the compositing of data from a number of orbits, and may also involve the use of a 'background field' derived using prior data.

1.5 Status of Document

The system concept for the EPS ground segment presented in this document supersedes that presented in RD1 which was distributed with the pre-phase A statement of work. The system concept reported here has been developed during the pre-phase A period, based on further definition and analysis of user requirements, development of system requirements and their design solutions and a series of interface discussions. In addition, the redefinition of the EPS, now based on METOP and including the possible use of the Data Relay Satellite (DRS), and the revised versions of instruments to be provided by NOAA have all now been taken into account.

1.6 Structure of Document

Section 2 defines all applicable and reference documents.

Section 3 provides background information for the EPS ground segment, including a description of the mission, METOP and the operational instruments. The basis for inter-operation with the NOAA ground segment is described and the scope of the EPS ground system is then considered with respect to the complete range of data access missions which can be provided from the observing system.

Section 4 summarises the principal user requirements and Section 5 describes one approach to the EPS data processing system which has been based on discussions with users and direct experience of current and planned NOAA systems. Section 6 presents a functional breakdown of the proposed ground segment, based on this proposed data processing system. The way in which the overall system is managed and operated, then is described in Section 7.

Section 8 identifies the main options for implementation of the system and a range of key issues are discussed in Section 9.

2 DOCUMENTS

2.1 Applicable Documents

AD1 EUMETSAT Polar System Ground Segment: End Users Requirements Document, EUM-EPS-PRD-SPE-92-001, Issue 2, 23-10-92

2.2 Reference Documents

RD1 EUMETSAT Polar System Ground Segment Overview, ESYS-91011-02, Issue 2, 24-07-g 1

RD2 EPS Ground Segment Working Assumptions on Interrelationships with the IASI Project, EUM-EPS-SPE-92-16, Draft 1, 11-M-92.

RD3 EPS Ground Segment Phase A Working Assumptions on Interrelationships with the MSG Ground Segment ***(being drafted)***

RD4 EPS Ground Segment Phase A Working Assumptions on Interrelationships with the Global Telecommunication System (to ***be drafted)***

RD5 EPS Ground Segment Phase A Working Assumptions on Interrelationships with Space Segment ***(to be drafted)***

RD6 EPS Ground Segment Phase A Working Assumptions on Interrelationships with NOAA (ro ***be drafted)***

RD7 EPS Ground Segment Phase A Working Assumptions on Interrelationships with European Global Data Users ***(to be drafted)***

RD8 EPS Ground Segment Phase A Working Assumptions on Interrelationships with European Earth Observation Networks (to ***be drafted)***

RD9 EPS Ground Segment Phase A Working Assumptions on Interrelationships with the Data Relay Satellite Ground Segment ***(to be drafted)***

3 BACKGROUND

3.1 The EPS Programme

The operational data required from polar orbiting satellites by the meteorological community are provided by a range of sounding instruments (infra-red and microwave), an imager and an in-situ data location and collection system. For over 30 years, these requirements have been met by a system of meteorological satellites in sun-synchronous polar orbits, procured and operated by NOAA. This system includes two satellites with similar payload complements;- one maintained in a morning orbit and the other in an afternoon orbit. This provides full global coverage for the meteorological user community, four times each day.

Whereas in the past, NOAA has operated both morning and afternoon satellites, the last NOAA satellite in morning orbit is currently scheduled for launch in 1997. All subsequent NOAA polar satellites will be in an afternoon orbit. These will therefore need to be complemented by a series of morning satellites to be provided and operated by EUMETSAT.

On the basis of current EUMETSAT planning, the operational meteorological instruments will be included on the METOP mission, with a scheduled launch date for the first satellite in the year 2000. It is currently anticipated that the EPS instrument set will be based on the NOAA instruments (AVHRR, HIRS and AMSU-A) together with MHS and an advanced sounding instrument such as IASI. These instruments are defined below in Table 3-2. METOP will also include a climate monitoring payload, but this is not considered further in this document.

3.2 METOP

The concept for METOP is focused on meeting the requirements of the operational meteorological community together with those of the emerging climatological community. The mission will be implemented jointly by ESA and EUMETSAT. ESA will assume the responsibility for developing the space segment. EUMETSAT will develop the ground segment and ensure operations and continuity of data services over the programme lifetime.

The basic requirements for the METOP space system are given in Table 3-l.

Table 3-l Basic Requirements for the METOP Space System

Spacecraft Parameter	
Orbit characteristics:	
Sun synchronous design range	07:30-10:00 hours
Nominal equator crossing time	10:00 hours
Tolerance	+/- 5 minutes
Ascending or descending	ascending
Altitude design ranges	824-1100 km
Altitude nominal value	850 km .
Altitude variation	frozen
Sub-satellite knowledge	+/- 1 km
Instantaneous attitude	0.05 degrees
Alignment between instruments	0.03 degrees
Direct broadcast services:	
HRPT frequency (basic)	1701 MHz
HRPT data rate	3.5 Mbps
LRPT frequency (basic)	137.1 Mhz
LRPT data rate	72 kbps
Global data service	X-band, DRS

3.3 The EPS Operational Meteorological Payload and Data Transmission

Table 3-2 provides a summary of the planned operational instruments, together with details of their data transmission.

Table 3-2 Details of Operational Instruments

(Data rates quoted in this table do not include the overhead for packetisation or communications protocol.)

	Operational data sources			*Data services*		
	Instrument	*Derived Products*	*Data rate (kbps)*	*Local LRPT VHF*	*Local HRPT S-band*	*Global X-band/ DRS*
AVHRR	Advanced Very High Resolution Radiometer	cloud cover, sea surface temperature	1,044 (high)	·	•	•
		ice, snow, vegetation characteristics	42 (low)	•		
HIRS	High Resolution Infra-red Sounder	temperature and humidity profiles, surface temperature, cloud parameters, total ozone	3.5	•	•	•
AMSU-A	Advanced Microwave Sounding Unit-A	temperature profile soundings	1.5	•	•	•
MHS	Microwave Humidity Sounder	humidity profile soundings, cloud liquid vapour	4	·	·	•
IASI	Infra-red Advanced Sounding Instrument	improved vertical resolution for temperature and humidity profile sounding, surface temperature, cloud parameters, total ozone, ozone profile, minor constituents	1,500		•	•
SEM	Space Environment Monitor	space environment data in support of on-board failure analysis	0.16	•	·	·
S&R	Search and rescue	transponder only				
ARGOS	Data location and collection package	collects and retransmits environmental data from gauges, sensors on platforms on land, ice and sea	2.6	•	•	•
MCP House-keeping data		instrument status and timed orbit, satellite location data. Updated every second. Observational pixel location to accuracy of 1 km	2	•	•	•
MCP Admin message		calibration data plus notification of any planned data interruptions	1.3	·	•	•

As indicated in Table 3-2, local coverage data may be provided to meteorological users via direct broadcast in low resolution (Low Rate Picture Transmission (LRPT)) or in high resolution (High Resolution Picture Transmission (HRPT)). LRPT is a new VHF digital service which will replace the currently used Automatic Picture Transmission (APT) system. Continuous transmission of payload data will be provided so that any ground station in any part of the world can receive local data when the satellite is overhead. Full resolution, global data will be provided by on-board storage combined with dumping to ground every orbit via X-band. However, since the ESA Ministerial meeting in Granada, the possibility now exists to use DRS for transmission of some global data. It is anticipated that this will provide a supplementary data service to X-band although the full impact of DRS on the global data acquisition scenario does need to be analyzed in the

Phase A.

Both the direct broadcast and global data service will use packet telemetry in line with Consultative Committee for Space Data Systems (CCSDS) recommendations. Both services will also include satellite attitude and orbit location telemetry together with the payload data.

3.4 Basis for Cooperation between EPS and NOM

Both the future morning (EPS) and afternoon (NOAA) satellites intend to carry a similar meteorological payload to that defined in Table 3-2. One notable difference is likely to be the advanced sounders. EPS is considering IASI, NOAA a rescoped version of the AIRS instrument. EPS and NOAA will also adopt a comparable approach for the global data service and provide compatible direct broadcast data services (HRPT and LRPT).

Global data at full resolution are stored on-board and down-linked each orbit via X-band. While the satellite is transmitting recorded global data to the data acquisition station, it will not necessarily be able to continue to record on-going data observations. Therefore during the dump period, the observed data are broadcast to a HRPT station located at the acquisition station. These data are then merged with the recorded data to derive global coverage.

Two data acquisition stations ate required at high latitudes to receive global data dumps from every orbit of each satellite. As indicated in Figure 3-1, the morning satellite will down-link recorded and real-time data to the data acquisition station in Europe for most orbits, with blind orbit coverage being provided by NOAA. Similarly, data from the afternoon satellite will be down-linked primarily to Fairbanks, Alaska, with blind orbit coverage being supported by EUMETSAT from the European station. In this way, the morning and afternoon satellites provide complete global coverage of the Earth's surface, four times a day.

Processing of the global data obtained from the two satellites is shared between the two ground systems. Each performs level lb processing immediately on receipt of data from either the morning or afternoon satellites. These level lb data are the exchanged between the two ground systems. Consequently, the level lb processing needs to be standardised between EPS and NOAA, so that a common method is used and comparable information is produced from each ground segment for global data users.

Each system may then decide independently on the requirements and methods for generating higher level, geophysical products (at levels 2 and/or 3). Each system will also have a responsibility to provide data and products from its own satellite for distribution via the GTS, to operate a data archive and retrieval system and provide a full range of complementary catalogue and user services.

3.5 Scope of the EPS Ground Segment

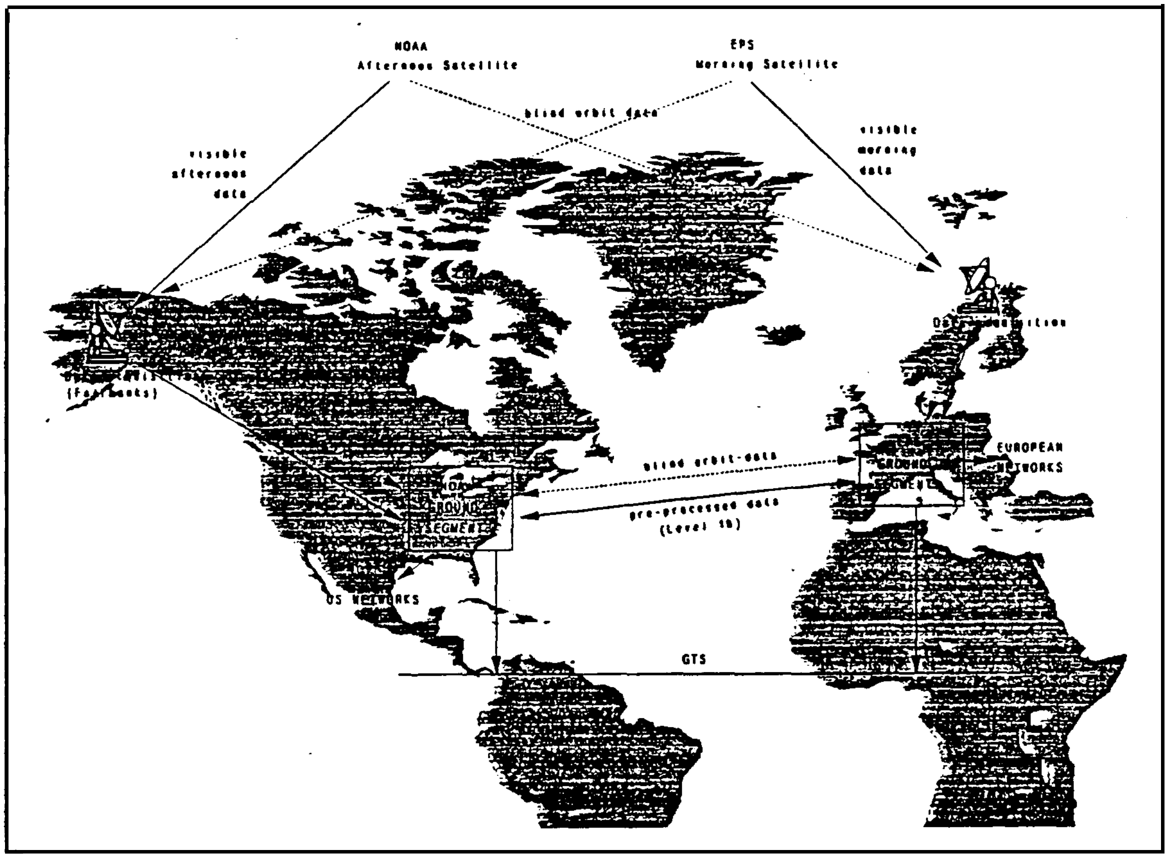

Figure 3-l Coordiiated EPS and NOAA Global Data Service via X-band

Figure 3-2 provides an overview of the key data inputs to the EPS ground system, the functions which need to be performed within it and the various forms of data access which are provided to users.

Global sounding and imagery data from the morning and afternoon satellites are input to the system, as described in Section 3.4 above. The ground segment needs to be able to cope with data from more than one morning or afternoon satellite in orbit at the same time. This will occur when a follow-on satellite is undergoing commissioning. These global data provide the main system driver for the ground segment in terms of payload data handling. From these input data, the objectives for the GLOBAL DATA ACCESS MISSION can be fulfilled. These include the delivery of quality controlled global data and products from the EPS sounders, imagery and ARGOS to operational users with minimal delay and not more that 2.25 hours from observation. The sounding and imagery instruments on the EPS system are viewed as a composite system, and the complementary role of all instruments to the observing problem is recognised in the proposed data processing system.

Also included in this global data access mission, is the delivery of regional data. This is a geographical subset of the global data covering Europe and its approaches, including the Eastern

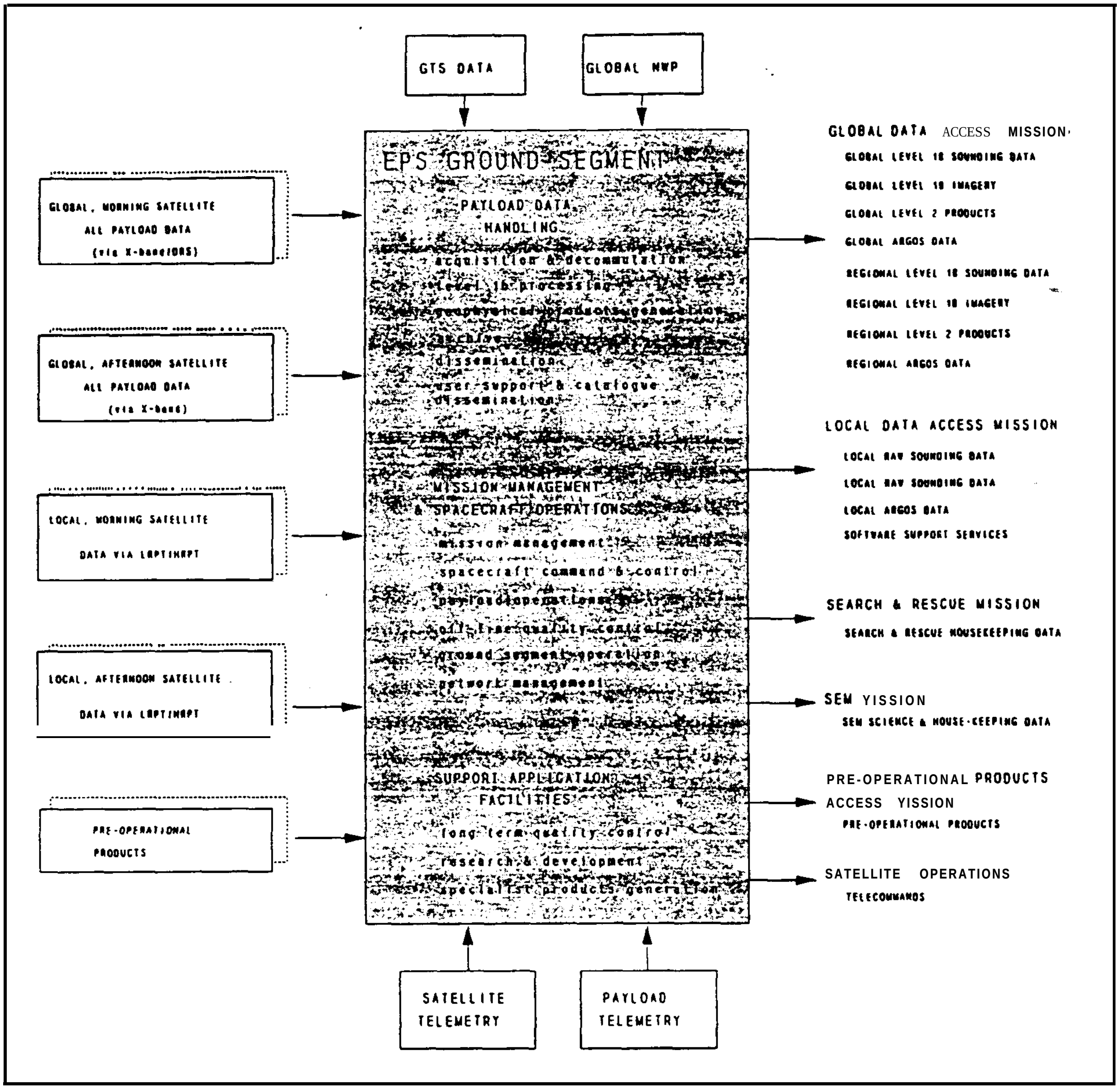

Figure 3-2 Key Objectives, Data Inputs and Scope for the EPS Ground System

Atlantic, the Middle East, Northern Scandinavia and the Arctic region. This area is of particular interest to many meteorological centres within EUMETSAT member states which do not operate global models.

The HRPT and LRPT data transmissions are monitored by the EPS ground system and a range of software support services are available to assist local meteorological users in the acquisition, processing and quality control of these data. However, the LOCAL DATA ACCESS MISSION is viewed only as a raw data dissemination service by the EPS ground segment. No central processing or dissemination of local data is undertaken. HRPT and LRPT systems comprise user acquisition, processing and archival functions which are considered to be independent of the system. The only exception to this is the direct broadcast data which are received to ensure full global data during tape recorder playback.

House-keeping data from the S&R and science and house-keeping data from SEM are routed through the EPS system to NOAA. The only data analysis undertaken within the EPS system for these instruments is monitoring to ensure their safe functioning. Thus the SEARCH AND RESCUE MISSION and the SEM MISSION do not place vigorous demands on the ground segment.

Data from the climate monitoring instruments also carried on METOP are routed through the EPS system to the Support Application Facility/ies responsible for the climate monitoring mission. The only operational data analysis currently envisaged within the EPS system for these instruments is monitoring to ensure their safe functioning.

Data from other Earth observation missions operated by ESA, NASA and NASDA are also of interest to develop new and validate existing operational meteorological applications. The PRE-OPERATIONAL PRODUCTS ACCESS MISSION will provide access to products (including fast delivery) from the various international programmes, for the operational meteorological user community, and alongside the operational data. The user requirements for products from pre-operational instruments are included in AD1. Examples of instruments of particular interest and which have been assigned a high priority by the users include AATSR, MIMR, SSM/I, ATLID and ALADIN.

To fulfil these mission objectives, the proposed EPS ground system is considered to comprise the following elements:

Operational Facilities

- the payload data handling component including data acquisition and decommutation, level lb data processing, product generation, archive, dissemination, catalogue and user services

- mission management and satellite operations perform a range of monitoring, control, system maintenance and upgrade tasks for all components of the space and ground system, in support of the meteorological missions.

Support Application Facilities

- off-line quality control

- special products

- research and development.

As well as global data from the polar satellite and from other non-meteorological, independent data from the GTS or global NWP centres will also be required for routine quality control and validation.

3.6 External Interfaces

Figure 3-3 identifies the main external interfaces for the EPS ground segment. The requirements for each of these interfaces is discussed below and more detailed consideration of data to be exchanged, and the particular characteristics of these communications links is included later in Section 6.

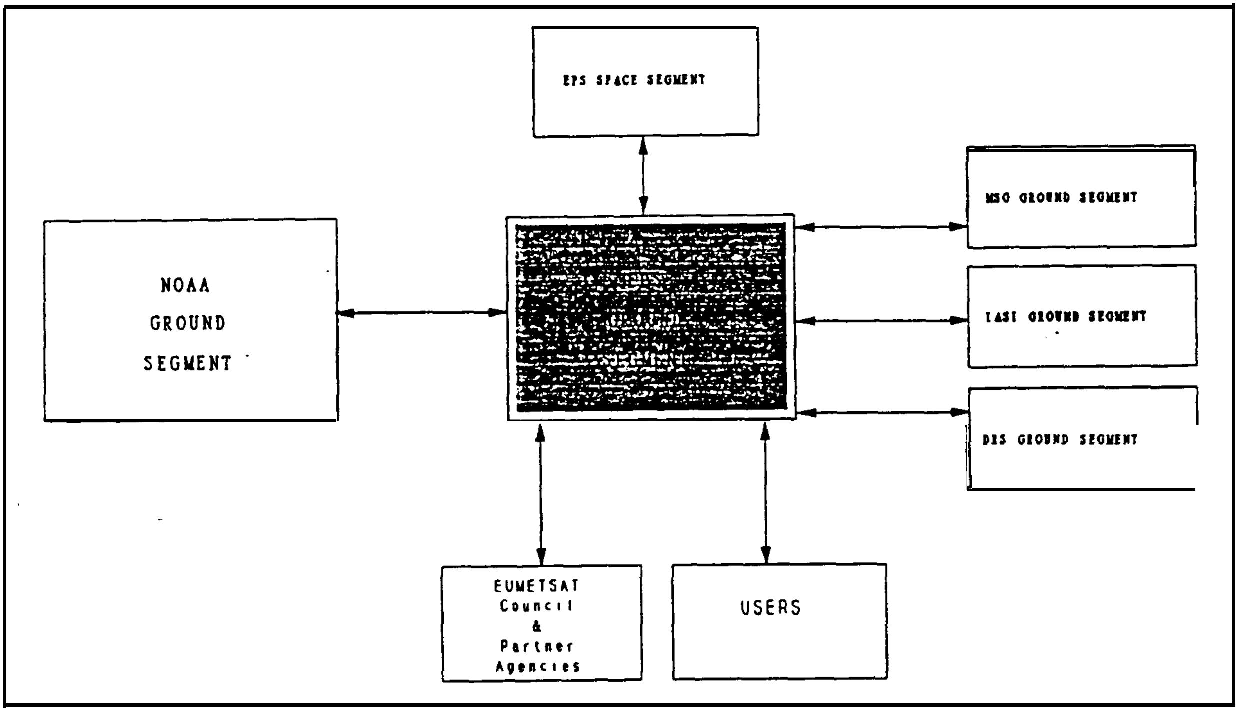

Figure 3-3 EPS Ground Segment External Interfaces

3.6.1 EUMETSAT Council & Partner Agencies

A link between the mission management team of the EFS ground segment and EUMETSAT Council, together with other relevant bodies within partner agencies (such as ESA, NOAA, ASI, CNES, the European Commission (EC)) which have an involvement in the mission, will be necessary for strategic management and long term planning.

3.6.2 Space Segment (RD5)

Interfaces with all morning (EPS) and afternoon (NOAA) satellites which are in orbit need to be provided for receipt of payload data (x-band, DRS (for EPS), S-band and VHF) and for operation and control of the satellites and their payloads (S-band). Back-up commanding services may be provided on a reciprocal basis by each ground system.

3.63 NOAA Ground Segment (RD6)

This interface will primarily support the cooperative and inter-operation requirements between the NOAA and EPS ground systems. Both high rate science data as well as management and daily operations information will need to be exchanged on a routine basis.

3.6.4 MSG Ground Segment (RD3)

The inter-operation potential between the proposed EPS and MSG systems does need to be studied both from a user and systems perspective. However, this need not imply a complex joint processing scheme, but simply the ability to transfer data from EPS to MSG. It is currently assumed that the EPS ground segment will provide certain products to MSG including polar cap winds and cloud mosaics to supplement MSG products. Level lb atmospheric products (temperatures and humidity profiles) for the lower atmosphere below 500 hectoPascals for the MSG European section could also be provided to support the MSG atmospheric stability products. Level lb data for calibration of MSG radiometers will also be provided.

3.6.5 IASI Ground Segment (RD2)

An interface with the IASI ground segment also needs to be established. In preparation for and also during the first flight of IASI, it is assumed that the IASI Project Team will provide support to the data processing and quality control schemes for IASI which will be embedded within the general operational EPS processing system. The EPS ground segment will undertake acquisition, level lb processing, geophysical product generation and archiving of the global data together with dissemination to the operational meteorological users. The IASI project will also provide support to the commanding, monitoring, fault and failure investigations for the instrument. All full resolution global level lb data and geophysical products will be provided to the IASI ground segment for detailed analysis and development, but also for distribution to users outside the immediate operational meteorology community.

3.6.6 DRS Ground Segment (RD9)

An interface with the DRS ground segment will be required for gaining access to DRS resources for EPS and for scheduling.

3.6.7 Users (RD7, RD8)

A whole range of meteorological and also external users will, receive data from EPS. The various user groups are described in more detail in Section 4. These users will also wish to interact with the system for information, to gain access to archive data and to be kept informed of service availability and future system changes.

It is anticipated that the GTS will continue to provide a worldwide data distribution service for a subset of data and products from the polar observing system. An interface with the GTS (RD4) will permit the provision of quality controlled satellite observations and derived products from EPS. It will also provide a source of independent meteorological observations for the processing systems within EPS, for quality control and validation purposes. A series of additional higher rate data dissemination networks are envisaged to provide European users with EPS data.

4 PRINCIPAL USER REQUIREMENTS

This Section summarises the principal user requirements for the EPS ground segment. More detailed information is provided in AD1.

4.1 Operational Meteorological User Groups

The EPS ground system will be designed primarily to satisfy the requirements of operational meteorologists within Europe. However, the requirements of NOAA, as a major provider of the instruments and the world-wide user community organised within the framework of the WMO must also be taken into account. Based on this international user community, a range of categories of user have been assumed for this concept of the EPS ground segment.

- Global Data Users

  These include meteorological centres in Europe, which run global NWP models in an operational environment, and which need level lb imagery and sounding data with minimal delay and not more than 2.25 hours from observation. These centres will also require level 2 geophysical products at a global scale. Global data users currently include Bracknell, Offenbach, Paris and the European Centre for Medium Weather Forecasting (ECMWF) in Europe, although further centres could evolve during the lifetime of the EPS ground segment. These centres typically have their own extensive processing facilities and expertise to develop and operate data and product processing of satellite data. They may also have independent archives to service their internal research and operational needs. A preliminary list of products is given in AD1.

- Regional Users

  These are more numerous and include EUMETSAT member states' meteorological centres which run regional weather forecasting models. These users requite access to regional European data and level 2 geophysical products, at both a regional and global scale. They require delivery of data and products with minimal delay. They will also require access to archive/historical data, at varying levels of processing.

- GTS Users

  WWW and World Climate Prediction (WCP) Centres, organised within the WMO framework also wish to continue to receive a range of data and products from the EPS via the GTS. For the purposes of access to archive data, these users will be classified as external users.

- **Local Users**

Meteorological users distributed globally, have LRPT and/or HRPT terminals to receive broadcast data directly from the satellite. These users will rely on the EPS ground system to provide support in software for navigation, calibration and quality control of the local data. As these procedures will essentially be the same as those for global data, the EPS ground segment should coordinate the exchange of these essential level lb algorithms whilst allowing local users to add in their own routines to meet their specific needs.

- **External Users**

These include user groups outside the European operational meteorological community. For example, the general meteorological community (ad hoc data requests), global environmental research programmes, the boarder European Earth observation community served by ESA Earthnet or planned European Commission initiatives may also require access to data and products from operational meteorological products. The requirements from these external users are still to be determined.

NOAA is not considered merely as a 'user' of the EPS ground segment system, as it is both a user and a provider of data. It is thus considered as a major system interface and indeed, as discussed in Section 3.4, its relationship with the EPS is key to the inter-operation of the global operational meteorological system and to meeting the users' requirements, particularly for global data.

As well as being **users of EPS data and products, certain global and regional centres within Europe, may also form an integral part of the EPS ground environment as SAFs.**

4.2 Archive Data

Although the EPS ground segment system will primarily be geared to providing global data for operational applications, users will also need access to historical data with more relaxed time requirements. As well as data and products from the morning and afternoon satellites, this will include background fields used in product generation and quality control. Such archive data and products will support case studies, research applications, climatology, special investigations and product development within the EPS ground segment system itself, the EUMETSAT member states and the broader WMO user community.

A full range of catalogue, browse, quick look facilities and data retrieval mechanisms are required to support these users. It is anticipated that all of the level lb data should be archived indefinitely to enable reprocessing to be undertaken, should this become required.

4.3 Compatibility

The EPS ground segment must provide services and deliver data and products which are compatible with the continuing (and also evolving) NOAA system. Compatibility will need to be addressed over a range of **ground segment activities including:**

- development of algorithms and software at least for deriving level lb data
- data reception facilities **and** support to level lb processing for local users
- inter-operability of archiving, catalogues and data dissemination systems.

European users require that at least level lb **data** received from the NOAA and EPS systems need to be the same (taking due account of any differences in the space segment configuration). **Standardisation,** timeliness, accuracy and quality **are** all **vital aspects** of this process.

The compatibility of the EPS data dissemination system with'the system existing at implementation time and procedures used by the EUMETSAT member states and other operational meteorological agencies also need to be considered.

4.4 Access to Other Meteorological Data

Meteorological users within Europe **require** access to products from a **range** of **pre-operational** instruments which are being considered for the ESA, NASA and NASDA polar orbiting platforms.

Conventional observations, analyzed fields and **forecast** fields **are also required** within the EPS ground segment to support product generation and quality control. These data **are** available via the GTS and direct from NWP centres. Global based observation systems providing observations over the whole globe are presently exchanged between all WMO members over the GTS at **6-hourly intervals.** Within **certain** regional **areas,** surface observations are exchanged every 3 hours and bilateral arrangements provide exchange of hourly reports between some countries. The principal GTS centres in Europe are Bracknell, Paris and **Offenbach.** These receive all data to the full degree of efficiency of the GTS and one or two of these centres (for back-up) could provide these to the EPS ground segment.

4.5 User Interface with EPS Ground System

Users require a single interface for **requesting** archive data, reporting problems and gaining access to information about the **EPS** space and ground systems.

4.6 Operational Continuity and Reliability

The ground segment system **must** offer a truly 'operational' service to the meteorological community. Data and products must be available routinely on a 24 hour basis and over a period of 10-15 years. System performance, availability and continuity of services will therefore need to be guaranteed through an appropriate strategy for redundancy, back-up, system recovery and inter-operability, system security and data ownership.

4.7 Continued Development

Whilst fulfilling operational requirements, there is also a need to provide sufficient flexibility and the means for continued research and development. Processing algorithms will be subject to continued development even when data become operationally available after launch. Hence the system will have to provide resources for *experimental* development in parallel with routine operations.

The system needs to be able to accommodate growth and future developments in terms of additions to the currently defined operational or pre-operational instruments, increased data rates and changes in user requirements for processing. The design should be capable of accommodating &he increasing requirements in an evolutionary fashion, with minimal disruption and equipment replacement.

These development activities need to incorporate the relevant research activities, expertise and facilities of EUMETSAT Member States' meteorological facilities.

4.8 Quality Control

All meteorological users demand high standards of quality control. All applications emphasise the need for independent quality controlled products which include error estimation. To provide this, the quality and integrity -of-the EPS ground segment must be ensured at all levels within the system.

Quality control needs to cover three aspects:

- overall system performances (i.e. delivery of the required product, to the user within the timeliness requirement)
- on-line error assessment and quality flagging
- **off-line** activities.

Quality control procedures should remain independent of the use of satellite products. They must depend on the physics of the measurements and the errors expected to result from the atmospheric effects and the limitations of the algorithms employed. All data and products distributed from the system need to be associated with an individual error estimate. This must reflect parameters such as instrument performance, meteorological condition and the retrieval model.

5 EPS DATA PROCESSING SYSTEM

Before describing the organisation of the ground segment, the structure of the EPS data processing system needs to be considered. One important component of this is to examine what is required by the users (AD1), and to formulate a strategy based on what is currently being achieved, or planned within the NOAA National Environmental Satellite Data and Information Service (NESDIS) and other systems in EUMETSAT Member States and ECMWF. A report is being provided to EUMETSAT in February 1993, which includes a review of methods and algorithms for a range of meteorological products. The description below represents an early attempt to define a structure within which individual algorithms can be considered, defined and also modified. This systems framework provides a necessary starting point both for iteration and discussion with the users and for the ground system design activities.

5.1 Approach

The approach to defining the EPS data processing system which has been adopted here, is to group the products according to their relationship with the processing chain, rather than to their meteorological content. Some duplication of products will occur when different processing chains yield information on the same geophysical variable. Removal of such duplication needs to be attempted, however, although some products may have no external users, they may be required as inputs to other data processes within the system.

An outline of the proposed EPS processing system is provided in Figure 5-1, and data from each of the instruments, AVHRR, MHS, AMSU-A, HIRS and IASI are all considered. In Figure 5-1, a distinction is made between processes (P) and data sets (D). Sections 5.2 and 5.3 below define the contents of each process and data set identified in this Figure.

HIRS and IASI have been treated as functionally equivalent. Scientifically IASI represents an increase in the number (and spectral resolution) of channels and in horizontal resolution compared to HIRS. There may also be technical changes imposed by these increases in resolution, but such details have not been addressed here. It is envisaged that products based on either HIRS or IASI would be disseminated operationally, but that there would be a transition period during which both would be generated and assessed.

This system does provide the user with the level 2 products defined in AD1. Level 3 products have not been included. The generation of level 3 products from the level 2 data sets will require some process of mapping, cornpositing or analysis. Certain level 3 products such as sea surface temperature, sea-ice extent and snow cover will be required internally within the product generation system. However, it is not clear at this stage, whether level 3 products should be produced for distribution to users, by the EPS system.

A number of processes will require ancillary data. These include NWP fields, land/sea topography maps and level 3 maps for some geophysical parameters (eg sea surface temperature, sea-ice and

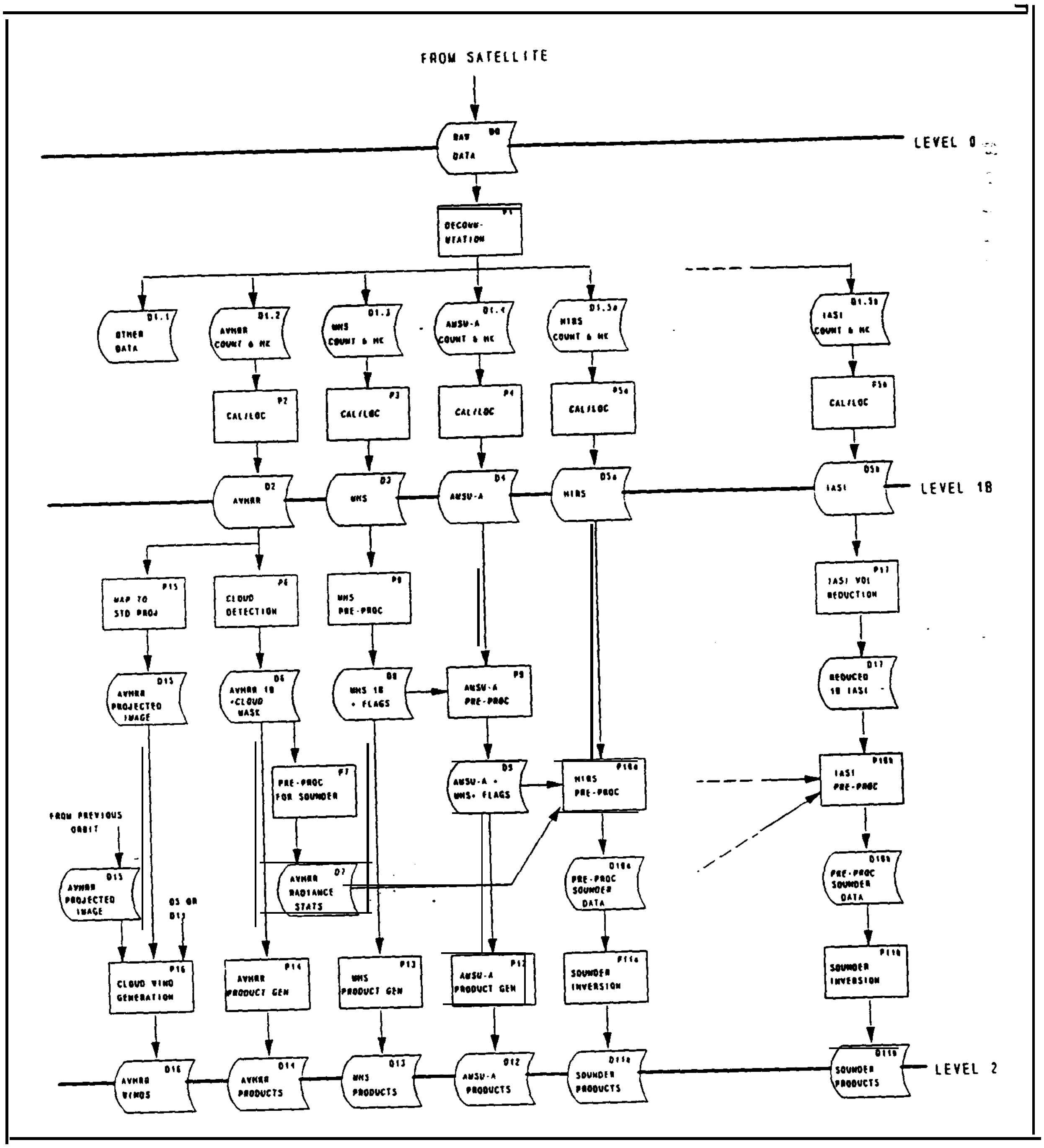

Figure 5-l EPS Processing System

snow cover).

5.2 Processes

P1 **Decommutatioo of raw data steam.** For simplicity, only one process is shown, but minor variations would be required to handle data from different sources such as EPS-playback, EPS-DRS, EPS-HRPT, NOAA-playback and NOAA-HRPT. Operational software to perform this function for NOAA data (ATOVS and AVHRR) will be developed by NESDIS for NOAA-K.

P2 **AVHRR calibration and Earth-location. Operational software to perform this function is** already used by NESDIS and may be developed further for NOAA-K. Software for this task has also been developed by a number of European operational centres.

P3 MHS **calibration and Earth-location. Operational software to perform this** function for similar NOAA data (AMSU-B) will be developed by NESDIS for NOAA-K, in collaboration with the UK Meteorological Office.

P4 **AMSU-A calibration and Earth-location. Operational software to perform this** function will be developed by NESDIS for NOAA-K.

P5a **HIRS calibration and Earth-location.** Operational software to perform this function is already used by NESDIS and will be developed further for NOAA-K. Software for this task has also been developed as part of the International TOVS Processing Package (ITPP) system used by some European operational centres

P5b **IASI calibration and Earth-location. If IASI** data undergo calibration on board, then 'calibration' here is very much simplified. Earth-location will be as for HIRS, with adjustment to the different scan pattern.

P6 **AVHRR cloud detection. This** process applies a series of tests to detect cloud-free and fully-cloudy conditions at a pixel level and outputs the results of these tests as a 'cloud mask'. Software performing functions similar to this module will form part of the NESDIS Revised and Advanced TIROS Operational Vertical Sounder (RTOVS/ATOVS) system (although applied to Global Ares Coverage (GAC) rather than full resolution AVHRR data). Other relevant systems containing similar algorithms include the cloud tests used in the NESDIS operational sea surface temperature scheme, and corresponding processes in operational AVHRR processing at the UK Meteorological Office (AUTOSAT2 and related AVHRR Processing system Over cLoud, Land and Ocean (APOLLO) systems), at the Centre de Meteorologie Spatiale (CMS), Lannion and at the Swedish Meteorological and Hydrological Institute (SMHI).

P7 **AVHRR pre-processing on infrared (IR) sounder fields-of-view. This** module derives statistical quantities (maximum, minimum, mean, standard deviation etc) of the AVHRR pixels identified as clear or cloudy in selected AVHRR channels on each IR sounder field-of-view for use in subsequent processing of the sounder data. Software performing functions similar to this module will form part of the NESDIS RTOVS/ATOVS system (although applied to GAC rather than full resolution AVHRR data). Changes to algorithm details are envisaged as part of the EPS ground segment to meet European requirements but within the same software architecture.

P8 MHS pre-processing. This module performs a number of pre-processing operations on MHS data. The main aim is to detect those conditions (eg precipitation) which would cause problems in subsequent modules. Software performing functions similar to this module will form part of the NESDIS ATOVS system. Changes to algorithm details are envisaged to meet European requirements but within the same software architecture.

P9 AMSU-A pre-processing. This module performs a number of pre-processing operations on AMSU-A data. The main aim is to detect those conditions (eg precipitation) which would cause problems in subsequent modules. It also maps MHS data to AMSU-A fields-of-view. Software performing functions similar to this module will form part of the NESDIS ATOVS system. Changes to algorithm details are envisaged to meet European requirements but within the same software architecture.

P10a HIRS pre-processing. This module performs a number of pre-processing operations on HIRS data. The main aim is to detect, and possibly adjust for, those conditions (eg cloud, solar reflection) which would cause problems in subsequent modules. It also maps AMSU-A/MHS data to HIRS field-of-views. Optionally, it could make use of information from AVHRR pre-processing. Software performing functions similar to this module will form part of the NESDIS ATOVS system. Changes to algorithm details are envisaged to meet European requirements, but within the same software architecture.

P10b IASI pre-processing. This module performs a number of pre-processing operations on IASI data. The main aim is to detect, and possibly adjust for, those conditions (eg cloud, solar reflection) which would cause problems in subsequent modules. It also maps AMSU-A/MHS data to IASI fields-of-view. Optionally, it could make use of information from AVHRR pre-processing. Software does not exist for this. Scientifically, the processing should mirror that for HIRS, with possibly more sophisticated treatment in some areas, including clouds, surface emissivity and ozone. Significant technical changes may be required because the IASI 'measurement vector' is much longer, but the same general software architecture as for HIRS is envisaged.

P11a Sounder inversion (HIRS, AMSU-A, MHS). This module estimates a vector of geophysical parameters (see D11a) from a vector of pre-processed level 1b data for

HIRS, AMSU-A and MHS (and optionally AVHRR) on the HIRS grid (or a subset of it). A number of scientific approaches are possible. The proposed baseline is the '1DVAR' or 'non-linear optimal estimation' approaches currently used at ECMWF and the UK Meteorological Office, which are also under investigation in the NESDIS National Meteorological Centre (NMC), the Canadian Atmospheric and Environmental Service (AES) and the Bureau of Meteorological Research Centre (BMRC) in Australia. It is likely to yield the most accurate products but with errors correlated to those of a forecast 'first guess'. It is planned to develop software performing functions similar to this module at ECMWF in collaboration with EUMETSAT for ATOVS and AVHRR.

P11b **Sounder inversion (IASI, AMSU-A, MHS). This** module estimates a vector of geophysical parameters (see D11b) from a vector of pre-processed level 1b data for IASI, AMSU-A and MHS (and optionally AVHRR) on the IASI grid (or a sub-set of it). An extension of the approach adopted for HIRS is likely to be preferred.

P12 **AMSU-A product generation. This optional module could generate a number of** products from AMSU-A and mapped MHS data where there is a strong scientific case for products on the AMSU-A grid. Software performing functions similar to this module will form part of the NESDIS ATOVS system. Changes to algorithm details are envisaged to meet European requirements but within the same software architecture.

P13 **MHS product generation. This** optional module could generate a number of products from MHS data where there is a strong scientific case for products on the MHS grid. Software performing functions similar to this module will form part of the NESDIS ATOVS system. Changes to algorithm details are envisaged to meet European requirements but within the same software architecture.

P14 **AVHRR product generation. This module** would generate products from AVHRR data (only) at a resolution of n*n pixels (to be decided for each product). Software performing functions similar to this module (although applied to GAC rather than full resolution AVHRR data) is currently used by NESDIS (eg for sea surface temperature and vegetation index). Other relevant systems include operational AVHRR processing at the UK Meteorological Office (AUTOSAT2 and related APOLLO systems), at CMS-Lannion, and SMHI and several other centres.

P15 **AVHRR mapping to standard projection. This module is required both to** generate mapped images **for** compositing and dissemination and also to provide input for wind generation. Maximum horizontal resolution should be maintained. Software to perform this function has been developed by several centres.

P16 **AVHRR cloud wind generation (high latitudes only). This** module performs pattern matching operations on mapped images from successive images and generates cloud displacement vectors. Height assignment is performed either using AVHRR level lb data and NWP fields or (preferably) using information from coincident sounder level lb data or products. Software to perform analogous tasks is present in the Meteosat system, which will be developed further for MTP and MSG.

P17 **IASI volume reduction.** **In** order to ease the problems associated with dissemination of global IASI level lb data and/or their processing in modules P10b and P1 lb, it may be necessary to reduce the data volume (in the radiance space) with minimal loss of information. A reduction from 2000 to 200 values per field-of-view is envisaged_ Research on the science of this module is required.

5.3 Data Sets

D0 Raw data from the satellite. There will be diierences in the data from different sources: EPS-playback, EPS-DRS, EPS-HRPT, NOAA-playback and NOAA-HRPT. These are not shown.

D1.1 Raw data from instruments other than the sounders and AVHRR. Processing and dissemination of these data are not considered here.

D1.2 AVHRR raw data, containing counts and instrument house-keeping information.

D1.3 MHS raw data, containing counts and instrument house-keeping information.

D1.4 AMSU-A raw data, containing counts and instrument house-keeping information.

D1.5a HIRS raw data, containing counts and instrument house-keeping information.

D1.5b IASI raw data. If calibration and interferogmm-to-spectrum conversion is performed on board, then this will contain calibrated level lb data and instrument house-keeping information.

D2 AVHRR level lb data

D3 MHS level 1 b data

D4 AMSU-A level lb data

D5a HIRS level lb data

D5b IASI level lb data

D6 AVHRR level lb data plus ‘cloud mask’ recording the results of cloud detection tests.

D7 Statistics of AVHRR level lb data (maximum, minimum, mean, standard deviation etc) on IR sounder fields-of-view.

D8 MHS pre-processed level lb data plus pre-processing flags on MHS grid.

D9 AMSU-A and MHS pre-processed level lb data plus pre-processing flags on AMSU-A grid.

D10a HIRS, AMSU-A and MHS (and optionally AVHRR) pre-processed level lb data plus pre-processing flags on HIRS grid.

D10b IASI, AMSU-A and MHS (and optionally AVHRR) pre-processed level lb data plus pre-processing flags on IASI grid.

D11a HIRS, AMSU-A and MHS (and optionally AVHRR) pre-processed level 1 b data plus derived geophysical parameters on HIRS grid. Derived parameters could include:

temperature profile
water vapour profile
cloud-top pressure and effective fractional coverage
cloud reflectivity (IR)
cloud liquid water content
cloud phase (microwave)
surface temperature
surface emissivity (microwave)
surface type (including snow cover, sea-ice)
ozone (total column)
radiation budget parameters

Where guess-dependence is significant (eg temperature profile), the guess values should also be stored. Quality control flags and processing audit should also be stored.

D11b IASI, AMSU-A and MHS (and optionally AVHRR) pre-processed level lb data plus derived geophysical parameters on IASI grid. Derived parameters could include:

temperature profile
water vapour profile
cloud-top pressure
cloud fractional coverage and radiative properties (IR)
cloud liquid water content
cloud phase (microwave)
surface temperature
surface emissivity (microwave and IR)

surface type (including snow cover, sea-ice)
ozone (profile)
radiation budget parameters

Where guessdependence is significant (eg temperature profile), the guess values should be stored. Quality control flags and processing audit should also be stored.

D12 AMSU-A and MHS pre-processed level lb data plus derived geophysical parameters on AMSU-A grid. Derived parameters could include:

precipitation
sea-ice extent
snow cover

Quality control flags and processing audit should also be stored.

D13 MHS pre-processed level lb data plus derived geophysical parameters on MHS grid. Derived parameters could include:

precipitation
sea-ice extent
snow cover

Quality control flags and processing audit should be stored.

D14 AVHRR pre-processed (and averaged) level lb data plus derived geophysical parameters on grid of n*n AVHRR pixels. Derived parameters could include:

albedo (cloud, surface, system)
sea surface temperature
land surface temperature
vegetation index
snow cover
radiation budget parameters

Quality control flags and processing audit should be stored.

D15 AVHRR images mapped to standard projection(s) at full resolution.

D16 Wind vectors derived from AVHRR images at high latitudes, together with cloud height (pressure) assignment and quality control information.

D17 IASI level lb data after volume reduction.

6 SYSTEM OVERVIEW .

6.1 Functional Overview

A functional overview of the operational EPS ground segment system is provided in Figure **6-l.**

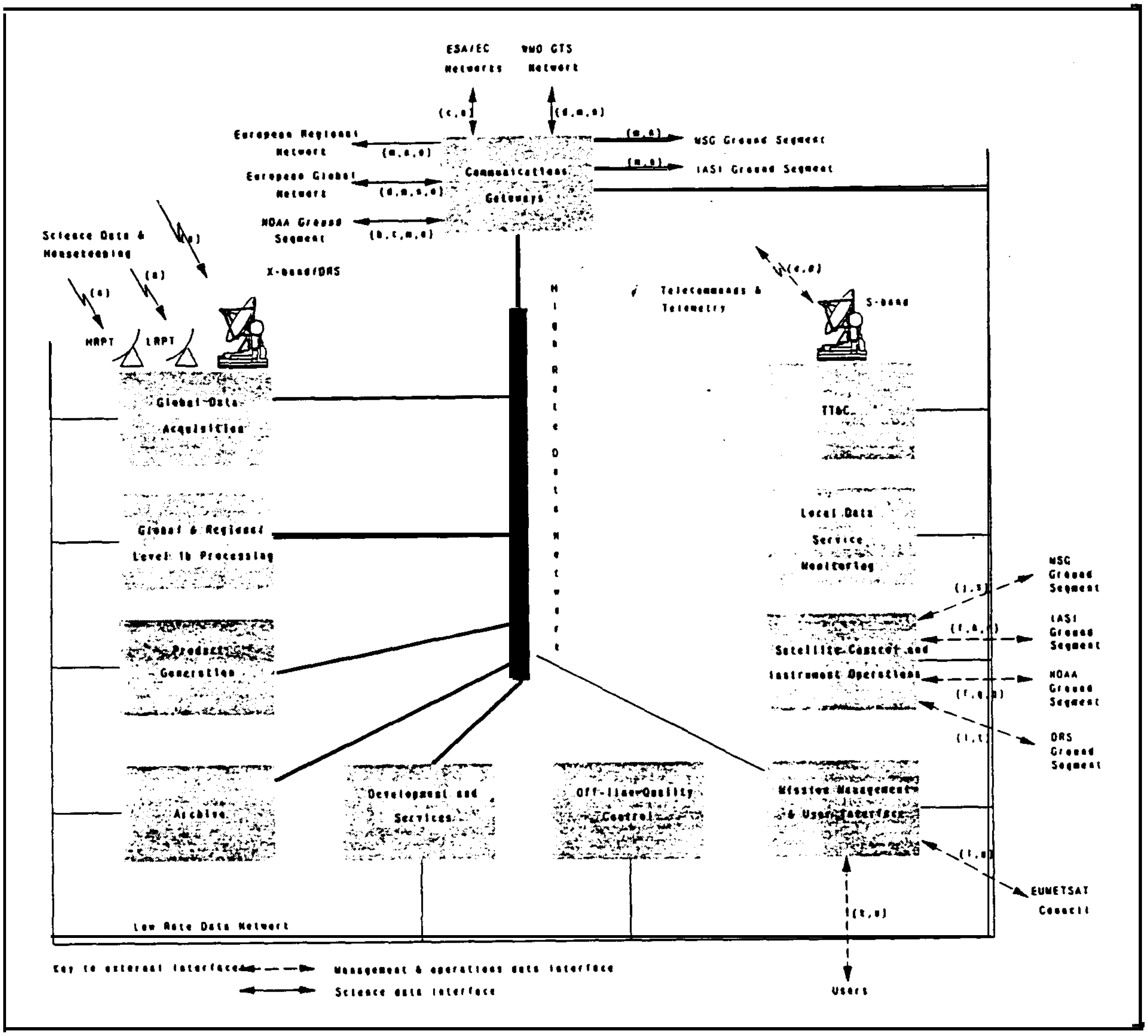

Figure 6-1 Functional Overview of the EPS Ground Segment
(Letters in brackets refer to data transfers which are described in Section 6.1.)

This functional overview provides a framework within which the data processing system described in Section 5 could be implemented within an operational environment, and products disseminated to users. This data processing system has to be supported by a. range of operational facilities providing user access services as well as satellite monitoring and control.

The key inputs to and outputs from the EPS ground segment system are listed below. These are distinguished in terms of their data content, and considered as either science data (plus associated house-keeping data) or management and operations data.

6.1.1 Science Data Inputs

(a) Raw data from the operational instruments, which include:

recorded data from the morning (EPS) satellite received at the European data acquisition station

recorded data from the afternoon (NOAA) satellite received at the European data acquisition station (blind orbit coverage)

real-time raw local data received via HRPT and LRPT.

(b) Level lb data, including

level lb data from the morning (EPS) satellite, received from NOAA (blind orbit coverage)

level lb data from the afternoon (NOM) satellite, received from NOAA.

(c) Products (level 2 and higher) from pre-operational instruments, which include

- ESA missions and including fast delivery products
- NASA platforms, comprising products received via the NOAA ground segment
- NASDA platforms, comprising products received via the NOAA g-round segment.

(d) Other operational meteorological data, which include

- conventional ground based observations from GTS, analyzed fields and forecast fields from global NWP models.

6.1.2 Management and Operations Data Inputs

(e) Satellite and payload telemetry, from the EPS space system.

(f) **Payload telecommands, from the payload** developers, acting in support of payload operations, especially during periods of commissioning or non-nominal conditions.

(g) **Management and operations data from the NOAA ground segment which enables inter-operation of the two systems and a coordinated approach to system evolution.**

(h) **Management and operations data from the IASI ground segment** which enables inter-operation of the two systems and a **coordinated** approach to system evolution.

(i) **Management and operations data from the DRS ground** segment which enables inter-operation of the two systems and a coordinated approach to system evolution.

(j) **Management and operations data from the MSG ground** segment which enables inter-operation of the two systems and a coordinated approach to system evolution.

(k) **User requests** for archive data and information about the **EPS** system.

(1) Strategic management directives, from EUMETSAT Council and partner agencies.

6.1.3 Science Data Outputs

(m) Operational level lb data, including:

level lb data **from** the morning operational imagery and sounding mission to European **Centres** and to NOAA

level lb data from the afternoon operational imagery and sounding mission to European Centres

raw and level lb **(TBC) IASI** data to the **IASI** Project Team during the first flight of this instrument

selected level lb and products to the **MSG** ground segment

a subset of level lb data to the GTS

S&R and **SEM** data **direct** to NOAA.

(n) **Geophysical products (recent and archive) are made available to all European users, to the** GTS and external user groups (for example Earthnet).

(o) **Pre-operational instrument products, are output** to EUMETSAT member states, and exchanged with NOAA.

6.1.4 Management and Operations Data Outputs

(p) **Telecommands** are output to the morning satellite, and also to the afternoon satellite (on behalf of NOAA, and in the event of non-nominal conditions).

(q) Management and operations data will be provided to the NOAA ground segment to ensure inter-operations of the two systems and a coordiited approach to system evolution.

(r) Management and operations data will be provided to the IASI ground segment to ensure inter-operations of the two systems and a coordinated approach to system evolution.

(s) Management and operations data will be provided to the MSG ground segment to ensure inter-operations of the two systems and a coordinated approach to system evolution.

(t) Management and operations data will be provided to the DRS ground segment to ensure inter-operations of the two systems and a coordinated approach to system evolution.

(u) System information is provided to users, to EUMETSAT Council and to partner agencies in response to specific queries and also as part of a routine reporting mechanism.

6.2 Functional System Description

An overview of each of the functional elements of the ground system and data networks are described in this Section.

6.2.1 Global Data Acquisition

As described in Section 3.4, a data acquisition station in Europe will receive data from all morning (EPS) satellites for visible orbits, and from the afternoon (NOAA) satellites for visible orbits which are blind to the NOAA CDA.

Tasks at the acquisition station will include:

- synchronisation
- decommutating
- removal of zero frames
- removal of overlapping data

- data merging and sequencing

- local storage (rolling archive) to maintain availability

- dissemination to **the level lb data processing function.**

6.2.2 Level lb Data Processing

Sounding and imagery data from the morning (EPS) satellite are then processed as soon as they are received, to derive level lb data. As described in Section 5.2; this involves three steps:

calibration. This transfers counts to level lb data, for each spectral interval of each instrument. The transformation is based only on engineering parameters (instrument characteristics and calibration data). Data from each of the instruments is calibrated immediately on receipt

Earth-location. Each measurement is associated with latitude and longitude, in relation to time and the scan angle of the satellite. This is calculated from ephemeris and navigation data

on-line quality control on the accuracy of the absolute calibration. Quality control flags are added to the data disseminated to us&s.

Within EPS, level lb processing is applied to data received from both the morning and the afternoon satellite and NOAA will undertake the same level lb processing to the data which it receives. As soon as the processing has been undertaken, these data are exchanged between EPS and NOAA. EPS will then disseminate the quality controlled level lb sounding and imagery data to European NWP centres in line with the overall user timeliness requirement of minimal delay and not more that 2.25 hours from observation.

A geographical subset of the level lb data, from morning and afternoon satellites, is also derived within EPS for distribution to regional forecasting centres in Europe, again within the user delivery time requirements. A subset of reduced resolution global level lb data, is also prepared for distribution to WMO users world-wide, via GTS.

All data disseminated to users from the EPS ground segment will be accompanied by quality control information. The level lb data are also made available for product generation and for archiving.

6.2.3 Product Generation

Data to be used in the generation of level 2 geophysical products are received from a number of sources:

- level lb data which are output from the level lb processing function or **received from NOAA**

- **analyzed** and forecast fields from a global NWP model, as these can play an important role in the retrieval, analysis and quality control of geophysical products

- conventional observations, analysis and forecast fields from the GTS.

One approach to the processing of level 2 from level 1 b has been described in Section 5. This series of processes would be undertaken as part of this function, according to a schedule and based largely on automated procedures. The schedule will be dependent on the availability of data and the relative priority of products. The procedures will be adjusted to take account of failures or drifts in the instruments. It is anticipated that as many tasks as possible will be performed automatically. An operator will monitor tasks and especially quality control.

Three different groups of geophysical products are anticipated:

- global

- regional (European area)

- product subset or reduced resolution (TBD) for distribution via GTS.

The following guidelines will be applied to the processing procedure:

- derivation of geophysical products will be based on a combination of level lb imagery and sounding data. The first step is often referred to as 'pi-e-processing'. This will be dependent upon the algorithm used for the retrieval of the geophysical parameters. Some auxiliary data have to be acquired at the time of pre-processing and at a spatial resolution compatible with the spatial resolution of the retrievals. These data, such as topography files, forecast fields, parameters from other instruments, will help the inversion process, or act as quality checks. It is possible that a range of inversion schemes are required for the retrieval of geophysical parameters

- on-line quality control is an essential and integral component of the level 2 processing. It will be applied to all data sets and processes which are used and error estimates for each product will be provided.

Routine and timely dissemination of products to operational meteorology users will be conducted according to a pre-defined schedule. Global and regional products will be prepared for distribution to global NWP and regional forecasting centres in Europe and a subset of products will be routinely disseminated to the worldwide community via GTS. It is likely that a direct transfer of products to the NOAA ground segment will not be necessary as NOAA intend to derive level 2 products from the morning level lb data received from EPS.

Selected EPS products will also be disseminated to MSG, to IASI and to external users via the appropriate data networks. All products and associated ancillary data will also be available for archiving.

Products from pre-operational meteorological instruments from ESA, NASA and other international missions will also be made available to the European meteorological community alongside the operational products. No processing of these pm-operational data or products is anticipated, the EPS system will simply act as a 'mail service'.

6.2.4 **Off-line Quality Control**

In addition to the on-line quality control procedures which are applied throughout the data processing system an off-line monitoring and evaluation function will also be performed within the operational ground system. It is likely that this will be supported by specific activities and long term trend analysis within SAFs, however, a coordination role is required to ensure that the system can evolve and improve upon any quality deficiencies which are detected.

A whole range of off-line quality control tests can be envisaged, such as consistency checks, checks on global averages, accumulation of long term data sets to check temporal variations, comparison and correlation of products to conventional observations and specific calibration campaigns.

6.2.5 Archive

The EPS ground segment will provide a long term archive of data, together with the necessary data management and retrieval system to ensure optimisation and coherent management of the data. Data will be archived according to the daily production schedule. This archive will include:

- level lb data from the morning satellite, including all satellite data, conventional observations and NWP fields which have been used to derive the level lb, thus enabling these data to be reversed to raw data if required. Compression may be applied to these data to be archived

- level 2 products derived within the EPS ground segment, including the morning and afternoon satellites. All observations and analysis fields used in quality checking and calibration and quality reports will also be archived with the products

- algorithms

- long term trend data on instrument and data processing performance.

Products from pre-operational instruments will not be archived as the EPS ground segment will facilitate access to the appropriate ESA, NOAA and NASA archives to meet the operational meteorological user requirements. However, a short rolling archive may be maintained to ensure user access to the products.

For data from the morning satellite, on-line access will be provided for a recent time period (such as 3 months), off-line access will be provided for the long term archive. In addition, a rolling archive of data from the NOAA system over a one month period may also be provided to give users fast access to recently acquired NOAA level lb data.

6.2.6 Local Data Acquisition Management

The EPS ground segment will undertake on-line monitoring of the integrity of HRPT and LRPT data services. This may be based on the HRPT and LRPT facilities located at the European data acquisition station (to complete the global coverage) or alternatively, additional HRPT and LRPT facilities may be located within the operational or support application environment.

To further support the local meteorological users, a range of off-line services will be provided which aim at coordinating the data processing system (up to level lb) of the local systems with those of the global EPS system. A set of software will be available for HRPT and LRPT users which will be comparable with, and updated in line with the global data system. Although the EPS will maintain this service, it will be the responsibility of the local user to customise, implement and maintain their systems. The EPS ground segment will also manage and monitor any system of technical control applied to the direct broadcast services.

6.2.7 Telemetry and Telecommand System

An S-band ground station is required for up-linking telecommands to and receiving telemetry from the morning satellite. This facility must be capable of handling up to two satellites in the morning orbit (one undergoing commissioning). This may also be used as a back-up command and transmission service for the NOAA satellite in the afternoon orbit, in the event of non-nominal operations. This back-up capability would be provided by the immediate uplink of pre-validated commands which have been received from NOAA and stored at the station, on receipt of authorization from NOAA. Telemetry received from the morning satellite would be routed directly to NOAA although a basic monitoring and alarm service may be provided. In a reciprocal way, NOAA could provide a back-up telemetry and telecdmmand facility for the EPS missions.

6.2.8 Satellite Control and Instrument Operations

This facility will undertake all tasks necessary to assure the continued operation of the satellite and payload. No analysis has yet been undertaken within the EPS programme for this facility. However, it is anticipated that this system will be comparable to those used for the ESA-ERS class of satellite.

Likely activities will include:

planning and scheduling for the on-board subsystems and resources, the operational meteorological instruments and the Meteorological Communications Package (MCP). In the event of non-nominal mission operations, this will seek to ensure continuous operation of the operational meteorological payload except in situations where satellite safety could be endangered. Considering the continuity and single mode of nominal operation for the meteorological instruments, instrument planning may vary only very little on a short term basis. However, instrument planning and scheduling will be more important when planning calibration activities, so as to avoid any conflicts with other instruments on the satellite

preparation and validation of payload and on-board subsystem commands, including maintenance and generation of command groups

reception and analysis of subsystem and instrument house-keeping telemetry. Monitoring, processing and analysis of telemetry will be performed, recorded and trend analysis applied both to real-time and historical data

monitoring and adjustment of the satellite orbit and attitude, including ranging and tracking activities

anomaly investigation and failure management, via liaison with the payload developers as appropriate

maintenance of house-keeping and instrument parameters database (such as out of limit values and command formats)

generation of administrative messages for up-link to the MCP. This provides information which users need accurately to calibrate the basic instrument data, and is derived from the ground segment quality control activities

provision of reports and operational information to the data processing system, to mission management, to NOAA and for users

maintenance of the MCP and IASI on-board software

running the spacecraft simulator

liaison with related ground segments such as NOAA, DRS, IASI and MSG where appropriate, to ensure the required level of coordination of system activities.

6.2.9 Mission Management. and User Interface

This function will undertake a hierarchy of activities and will contain management tools to support the monitoring and decision making process.

At the highest level, it will provide the management interface with EUMETSAT Council, with NOAA and other external agencies. With responsibility for the overall performance of the EPS system, this will address high level planning issues and have the necessary level of authority to reassign priorities in relation to system availability, production capacity and user requirements. This will include the specification and coordination of long term development activities for the ground system, with NOAA and with key users.

The major task will be the activity planning for the ground segment, with responsibility for ensuring the synchronisation, execution and quality of all operations and external interfaces. This will embrace:

- management of failures (space and ground) which impact the mission objectives
- monitoring, control and configuration management for all ground segment resources
- verification of the functionality, performance and end-to-end operability of the ground segment according to the specification of each mission phase
- planning and support for calibration campaigns
- managing the technical control of the direct broadcast system.

A single point of contact will be provided for user requests. This will address all information needs about the system, processing and dissemination systems, operations schedules and access to system catalogues, user guides and quick-look facilities. The catalogue and means of access will be standardised with NOAA and even other agency catalogues, perhaps via CEOS recommendations.

Retrieval and dissemination of data and products requested are handled by this function. Dissemination may use the existing networks, although in this, priority will be given to the operational data.

6.2.10 Development and Services

As a fully operational system, a full back-up philosophy and contingency planning determined by the Mission Manager needs to be implemented with support from this facility. This will be especially true during periods of multi-mission operations.

A centralised concept for managing the development and maintenance facilities required for the operational EPS ground system is established here, although infrastructure and staff may well be distributed within the support application environment. Development and services may include:

- maintenance facilities and staff for software and hardware fault diagnosis and correction, routine upgrades which continue to optimise the operational implementation

- research facilities including computing resources to support research teams undertaking continued evolution, development and refinement of the EPS data processing system and development of new products including specialised applications and level 3 products

- software development teams to implement major system upgrades or new developments

- simulation facilities and test tools for fault diagnostics (space and ground), integration and commissioning of new systems and upgrades and training.

Even after the EPS ground system becomes operational, the production software will be subject to evolution, taking into account the progress of NOAA and the operational meteorological community. This evolution must however, be pursued without disturbing the operational status and continuity of the system.

Research and development teams will have access to the operational libraries for data processing and operational data will also be accessible for evaluation. However, priority will always be given to the operational mission objectives.

6.2.11 Communications Gateways

A range of communications gateways support all data communications between the EPS ground segment and external networks. The basis for these interfaces has been considered in Section 3.6. Based on preliminary estimates of throughput rates, an early estimate of requirements for these external interfaces is given below.

- NOAA (8-10 Mbps) - primarily for exchange of blind orbit level lb data and global level lb data. Data compression may be used here, as the link must be sized to support the simultaneous transmission of data when both satellites are in phase. A back-up line is anticipated

- **European Global Data Network (8** Mbps) - for distribution of full resolution, global level lb data, geophysical products and historical data which have been requested and retrieved from the archive. This network will also provide EPS with access to analyzed and forecast fields. There are currently four global NWP centres to be served by this network in Europe, although this number is likely to grow during the operation of EPS. Data compression is also likely to be applied

- **European Regional Data Network** (100 kbps) - for distribution of regional level lb data, geophysical products together with historical data which have been requested and retrieved from the EPS archive

- WMO users (existing GTS X25) - for dissemination of selected global products and reduced resolution level lb data

- MSG (TBD) - for delivery of selected EPS level lb data and products

- IASI Project Team (TBD) - for delivery of global, full resolution IASI level lb data and selected geophysical products

- **European Earth Observation** Users (X25) - links with proposed ESA and EC networks are envisaged for systematic delivery of operational meteorological data and receipt of data from pre-operational meteorological instruments, including fast delivery products.

These data rates will need to be revalidated as the system requirements and system design proceeds.

Key features for these gateways include high reliability (including redundancy and storage capabilities) to minimise data loss and flexibility to deal with changes in communications needs. If satellite broadcast systems are to be used. then security of the data will also be an issue.

6.2.11 High Rate Data Network

This network will support high rate (greater than 64 kbps) data transfers of science data and auxiliary data sets between all elements in the EPS ground. segment, and is required to facilitate the timely processing of global data. Included in this network will be the communications media (for example, high rate LANs, leased lines and satellite links), the sets of equipment needed to interface with the network, protocols and network management functions.

It may well prove necessary to compress data to achieve an economic service. Indeed, included in the EPS data processing system (Section 5), is a process to reduce the volume of IASI data. Security of data is also an important factor, since any loss of information has to be acceptable to users and for their various applications'of the data.

6.2.12 Low Rate Data Network

This network supports low rate (lower than 64 kbps) data transfers between all elements in the EPS ground segment. A large variety of data types including telemetry, telecommands, scheduling data, management and control information are included. The technologies included may include LANs, PSNs, ISDN and dial-ups.

7 CONCEPT FOR MANAGEMENT ANTI OPERATIONS

Based on the overall mission configuration, the proposed data processing system and ground segment structure described in the previous Sections, this Section outlines a concept for management and operations of the EPS ground system. It is a preliminary view, and will evolve with the project. The overall concept for operations needs to be a hierarchical one, the principles for which are illustrated in Figure 7-l.

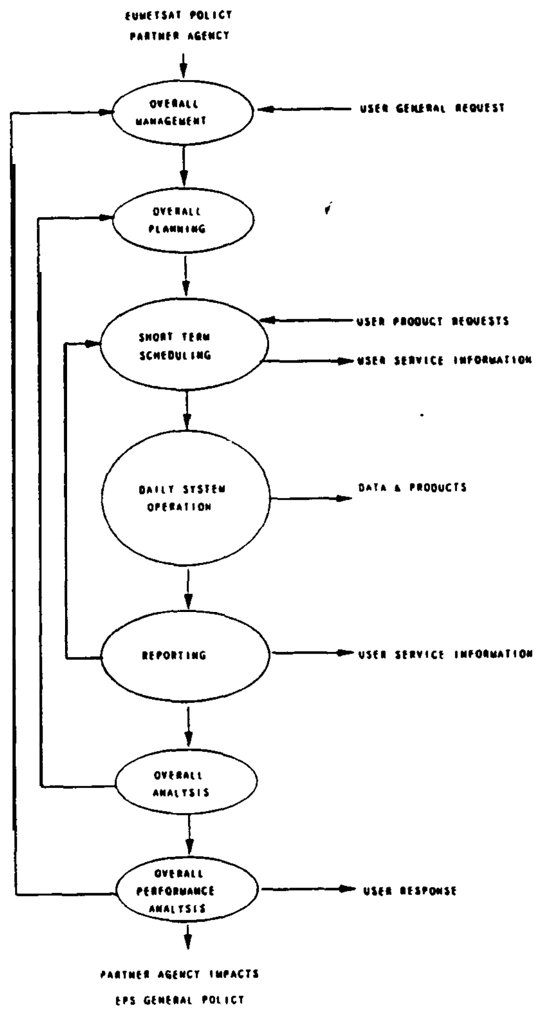

Figure 7-l Hierarchical Concept for Management and Operations

7.1 Overall Management and Planning

The proposed EPS system includes a complex operational data processing system, with a high number of external interfaces (supporting data input and dissemination). To support the users operational, availability, evolution and coordination requirements, the EPS system management and control must be centralised and supported, as appropriate by local management in any geographically distributed facility. It must maintain the operational status of the system, whilst supporting different combinations of morning and afternoon satellites which are in orbit at any one time. Future developments also need to be planned which do not interrupt the continuity, but improve the breadth and quality of user services.

7.2 Scheduling

The operational load of the overall ground segment will not be constant as the environment within which the EPS ground segment must operate will vary. A complex layering of activities for the ground segment can be envisaged which affects what resources are required and the flexibility needed for planning and scheduling operations.

The planned launch schedules and lifetimes of polar orbiting satellites carrying the operational imagery and sounding instruments are shown in Figure 7-2. This provides a basis for examining these layers.

At the first level, a **preliminary commissioning** phase can be envisaged in the period of preparation, up to the launch of the first EPS. During this period, blind orbit coverage for NOAA could be undertaken by the EPS ground segment, together with receipt of global level lb data and geophysical products_ These data provide opportunities for early testing of the data processing chains and data handling infrastructure and enable a progressive involvement and integration of the operational system into the existing meteorological framework within Europe. From the launch of the first EPS satellite, the full system would become available.

At the second level, there are periods of time where different numbers and combinations of satellites need to be supported by the ground segment. At any time, this may require simultaneous handling of data from two fully operational systems as well as additional satellites which are being commissioned ***or are*** at their end of life. At any one time, the ground segment must give priority to the operational rather than commissioning system, but there must be sufficient capacity to permit the necessary preparations for validation and phased introduction of new systems. Furthermore, the relative position of the morning and afternoon satellites ranges from the case where dumps occur almost at the same time and tunes when this is synchronised. This implies a tremendous range of variation of throughput and data processing load in the system.

At the third level, for each individual satellite, the full range of mission phases need to be considered including; participation in integration and testing of the satellite and instruments before

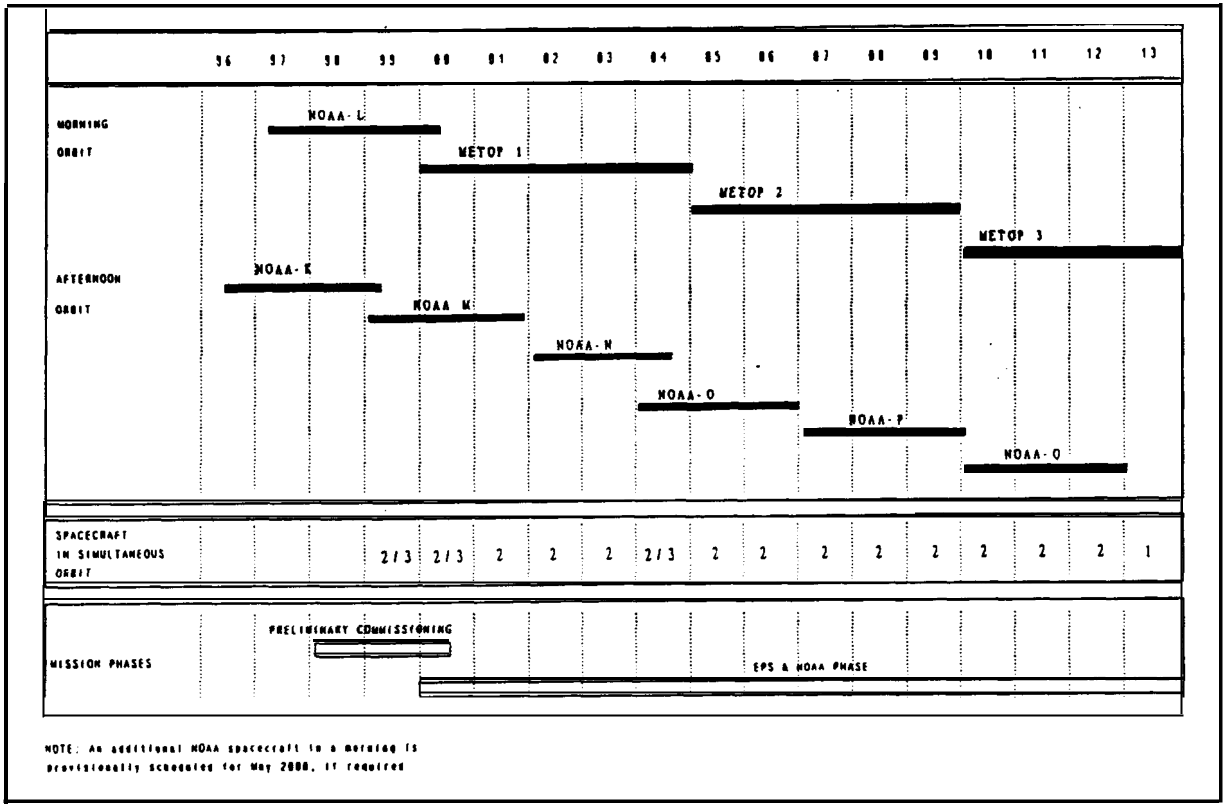

Figure 7-2 Launch Schedules for EPS and NOAA Spacecraft

launch, launch and low Earth orbit operations, check-out of the on-board systems and payload during commissioning phases, routine operations, non-nominal operations and end of life.

A key characteristic for this changing environment is that whenever a new system is introduced (whether spaceboume or within the ground segment), there must be an appropriate period of transition and validation where the new system overlaps with the existing phase.

7.3 **Daily Operations**

Based on daily schedules of global data dumps from the morning and afternoon satellite and the daily schedules of the availability and requirements for blind orbit operations, the EPS ground segment activities schedule will be derived. Such a schedule is illustrated in Figure 7-3, for the case on global data acquisition via X-band and HRPT.For the data of any given orbit, the level lb processing function shall be activated as soon as the first data of the orbit is received. In order to get all data through the system before data from the next orbit arrives, these data are 'piped' through the system to ensure that bottlenecks do not develop. This is not a direct pipeline system, as there will be a minimum (TBD) amount of data which is requited for processing, and particularly for validation purposes. Typically such a data block would be straddled by the on-board calibration sequence (for level lb data) i.e. corresponding to a scan line of data for AVHRR,

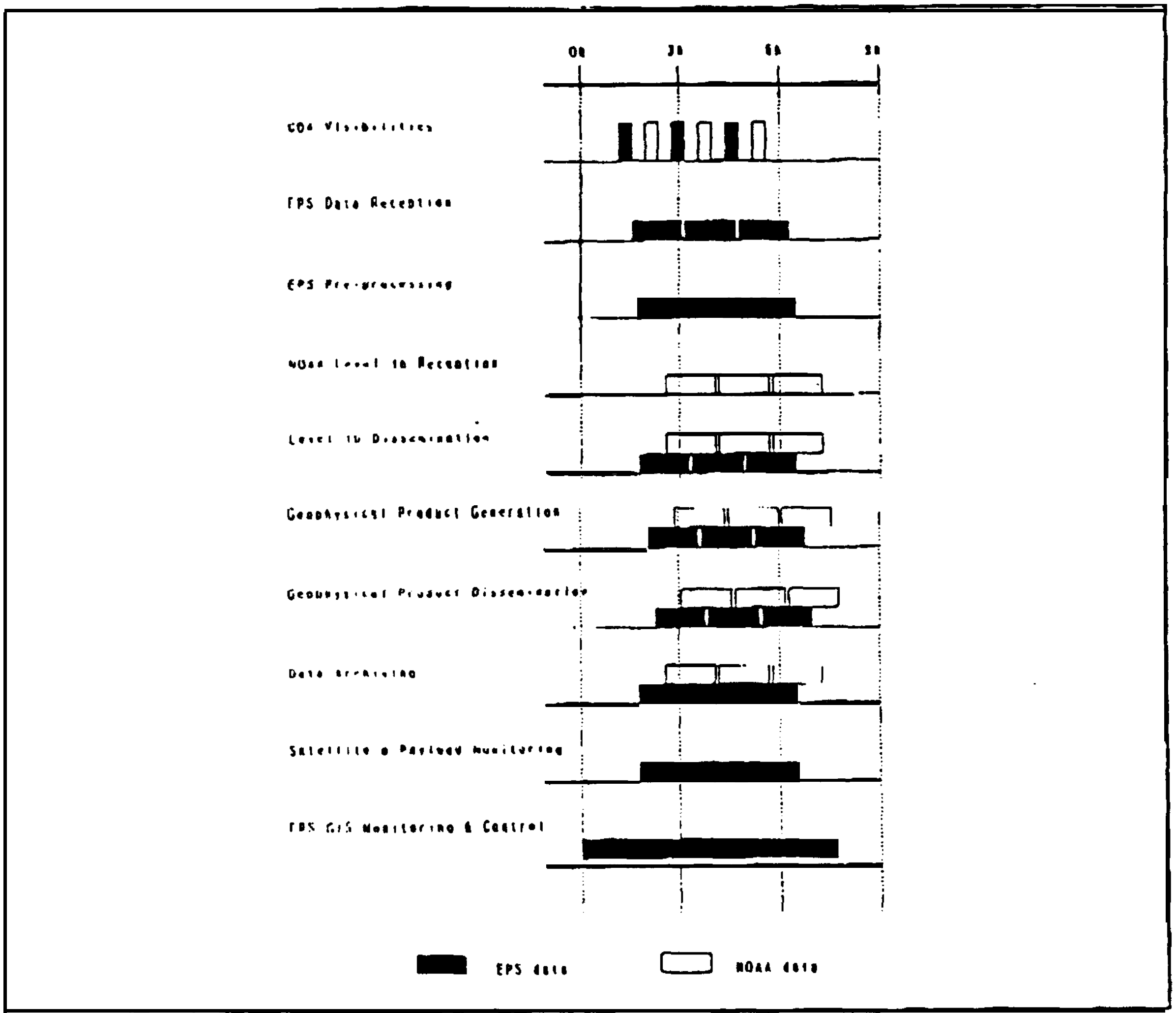

Figure 7-3 Daily Operations

AMSU-A and MHS and 40 scan lines (256s) for HIRS. For level 2 processing, some mapping across instrument fields of view will be required, this is indicated in the resolution column of the products tables given in AD1.

Under normal conditions, the key data reception and processing functions shall be run without the intervention of an Operator. The system needs to be designed with good *margins,* in particular for the communications links and the CPU capacities. The communications lines are a major cost driver (particularly in the operations phases) and need to be sized carefully.

In terms of daily operations and production of global data and products, the system will not primarily be an order-oriented system, However it must bc able to respond to user requests for additional or archived data. A single user interface is very important to ensure coordination of user requests. Highest priority will be given to the production and exchange of level lb data.

8 OPTIONS FOR IMPLEMENTATION

During the design of the EPS ground system, although the system will need to be optimised (particularly with respect to data communications), the opportunities for reuse of existing infrastructure and technical/scientific expertise within Europe will need to be systematically evaluated across all proposed EPS ground segment functions. The concept of SAFs has been established to enable the EPS ground segment to exploit these opportunities. Meteorological systems and facilities owned by EUMETSAT member states or by NOAA may offer cost savings and risk reductions for the EPS ground segment programme. The potential of these systems and facilities needs to be assessed against agreed requirements for the EPS. However, these options should not detract from a total systems approach at least during the early stages of the programme.

Table 8-l summarises the current range of options for implementing each major component of the ground segment. Options for each function are not necessarily linked to those for other functions.

Table 8-1 Options for Implementation of the EPS Ground Segment

Ground Segment Function	*Options*		
Global data acquisition	Competitive tender for EPS data acquisition station at northern latitude plus, if required, blind orbit coverage from one other US station.		
Level 1b processing for Global data	Collocated with the European data acquisition station.	Centralised and collocated with central EPS facilities within EUMETSAT headquarters.	Split IASI level 1b processing from other operational met instruments.
Local data service monitoring	An HRPT and LRPT included with the European X-band station to complete the global coverage and so that direct broadcast services can be monitored.		
Product generation	Centralised and collocated with central EPS facilities within EUMETSAT.	Collocated with a major European NWP.	
Archive	Centralised and collocated with central EPS facilities within EUMETSAT.	Distributed amongst EUMETSAT, NWP and other existing facilities within Europe.	

Ground Segment Function	*Options*		
Catalogue	Centralised and collocated with central EPS facilities within EUMETSAT. Single point at contact for users.		
TT&C	With data acquisition station in northern latitude. Back-up provided by back-up (NOAA) data acquisition station.		
Satellite control and instrument operations	Collocated with EPS facilities within EUMETSAT headquarters.		
Mission management and user interface	Centralised and collocated with central EPS facilities within EUMETSAT.		
Development and services	Undertaken at a selection of SAFs, including E - T headquarters, and under EUMETSAT coordination.		
Off-line quality control	Undertaken at a selection of SAFs, including EUMETSAT headquarters, and under EUMETSAT coordination.		

During the future definition and analysis of ground segment options, a number of factors need to be taken into account:

- development risk and schedule aspects
- management and operational impacts of a distributed versus a centralised system
- management and operational impacts of using established facilities versus new
- possibility of price reductions in reuse of existing facilities and operations staff versus possible cost reductions associated with collocation
- desirability of performing meteorological operations in an existing meteorological service environment where proximity to users may have a positive impact on overall performance
- the need to consider regional products in addition to global products
- evolution of operational software.

. Wherever the various components of the ground segment are implemented, *the overall* system design, development and acceptance of the system will be managed, by EUMETSAT. The focus of operations shall also *remain* at **EUMETSAT,** encompassed within the mission management and user interface facility. This shall act as the interface with all facilities, with external agencies and with users of the system. It will be responsible for the integration and continuation of operations.

9 KEY ISSUES

Throughout the EPS ground segment programme, there will be key technical and programme questions to tackle. This Section highlights some of the current requirement and system issues which have emerged from EUMETSAT work to date.

The design of this ground system, several key factors will need to be taken into account:'

- the need for operational data handling and full exploitation of all satellite information

- the importance of minimising any repetitive treatment of data (both within the EPS ground segment and in terms of data or products received from external sources) in the production of various geophysical products

- the potential benefits (both scientifically and fmancially) to be derived from coordinating the development and evolution of the system both with NOAA and other operational centres within Europe.

9.1 User Requirements

The high level requirements for the operational meteorological mission have now been established. A preliminary level of system analysis and algorithm assessment work has validated the feasibility of these although further design, performance and cost analyses needs to be undertaken.

The user requirements also need to be continually developed and refined based on visibility of the "evolving system concept and more importantly the emerging principles for data processing.

Possibilities to refine and to reduce the users demands in terms of timeliness, resolution or coverage will reduce system complexity and cost, and should continue to be evaluated and traded against the system implications.

For example, full resolution sounding and imagery data are included in this dissemination. Alternatively, a range of cloud parameters, derived from the full resolution imagery could be distributed for use with the sounding data.

9.2 The Retrieval Process

The derivation of geophysical products is an ill-posed scientific problem (i.e. multiple solutions will fit the observations). Within the EPS ground system, the work of several scientific groups will be instrumental in providing the basis for algorithms and processing procedures to ensure their expertise can be used both in the design, development and operation of the EPS data processing system.

Different groups of meterological users may wish to select different conceptual approaches to processing, with specific tailoring to suit their own levels of experience and specialised applications. This leads to a diversity of methods and consequent duplication of processing. Whilst a certain level of duplication, both within the EPS data processing system, and with certain EUMETSAT member state facilities will be inevitable, a balance needs to be achieved between coordinated development and operations whilst enabling users to evolve their own systems and environments.

9.3 **Quality Control**

Quality control is an important user requirement, and an important element of the data processing system. Much work needs to be undertaken in both specifying and implementing quality control, and providing quality information to users which is relevant and meaningful to their application of the products. A number of principles need to be applied in this area.

It is important to identify error types at all stages of the processing (random, systematic, rough, instrument, algorithm, time, space dependent). Data sets for validation also need to be identified and collected. These may be dependent or independent, measured or computed and the error types for all validation data sets also considered. Quality control checks then need to be defined. Are these on-line or off-line, how frequently are they applied, what severity levels are associated with the quality flags. Most importantly, quality control data must be meaningful, with respect to both the engineering or geophysical parameter and intended application.

9.4 standards

This document has stressed the high degree of interaction with external systems There is a need to define standards to enable interoperation with these external data networks and systems. These standards need to address a broad range of range of topics including data communications, archiving, interoperable catalogue systems, calibration and validation, directory networks and software development. Existing standards and new initiatives within NOAA, WMO, ESA, CCSDS and CEOS are all of relevance.

9.5 Data Networks

Due to the large volume of data required by users, in near real-time, there is a need to explore methods for reducing the data volume while preserving information content and ensuring reversibility. An assessment of achievable compression ratios needs to be undertaken, particularly with respect to operations costs together with the implications of compression/decompression steps within the system, including delivery to users and to NOAA.

The requirements for data distribution systems like **GTS,** but also additional systems need to be addressed for full resolution global and regional level lb and global products. It is likely that GTS can be used only for subsets of global level lb data. As the number of geophysical products required by users increase, then the need for a separate dissemination system will need to be evaluated.

9.6 System Complexity

The EPS ground segment, as described in this document is a complex, real-time system which interfaces with a range of external entities. To minimise risks during development, complex functions and interfaces should be validated as early as possible during the programme. Consequently, simulation and **prototyping** of the processing scheme, data flows and external interfaces will be a valuable approach. Phased releases of the system and decoupling of the different components will allowing testing and validation of all functions in a progressive manner.

10 ACRONYMS

AATSR	Advanced Along Track Scanning Radiometer
AES	Atmospheric and Environmental Service
ALADIN	Atmospheric LAser Doppler INstrument
AMSU-A	Advanced Microwave Sounding Unit-A
APOLLO	AVHRR Processing system Over cloud, Land and Ocean
APT	Automatic Picture Transmission
ASI	Agenzia Spaziale Italiana
ATLID	ATmospheric LIDar
ATOVS	Advanced TIROS Operational Vertical Sounder
AVHRR	Advanced Very High Resolution Radiometer
BUFR	Binary Universal Form for Representation of meteorological data
BMRC	Bureau of Meteorological Research Centre
CCSDS	Consultative Committee for Space Data Systems
CEOS	Committee of Earth Observation Satellites
CMS	Centre de Meteorologie Spatiales
CNES	Centre National d'Etudes Spatiales
DRS	Data Relay Satellite
EC	European Commission
ECMWF	European Centre for Medium range Weather Forecasting
EPS	EUMETSAT Polar System
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
GAC	Global Area Coverage
GENIUS	Global Environmental Network Information and User System
GCOS	Global Climate Observing System
GOS	Global Observing System
GTS	Global Telecommunications System
HIRS	High Resolution Infra-Red Sounder
HRPT	High Rate Picture Transmission
IASI	Infrared Advanced Sounding Instrument
IR	InfraRed
ISDN	Integrated Services Digital Network
ITPP	International TOVS Processing Package
LAN	Local Area Network

LRPT	Low Rate picture Transmission
MCP	Meteorological Communications Package
MHS	Microwave Humidity Sounder
MIMR	Multi-frequency Imaging Multiband Radiometer
MSG	Meteosat Second Generation
MTP	Meteosat Transition Programme
NESDIS	National Environmental Satellite Data and Information Service (NOAA)
NMC	National Meteorology Centre (NOAA)
NOAA	National Oceanic and Atmospheric Administration
NWP	Numerical Weather Prediction
PSN	Packet Switched Network
RTOVS	Revised TIROS Operational Vertical Sounder
SAF	Support Application Facility
S&R	Search and Rescue
SEM	Space Environment Monitor
SMHI	Swedish Meteorological and Hydrological Institute
SSM/I	Special Sensor Microwave/Imager
TT&C	Telemetry and Telecommand
VHF	Very High Frequency
WCP	World Climate Prediction
WMO	World Meteorological Organisation
WWW	World Weather Watch